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THE SANITARY CONTROL OF SWIMMING POOLS*

MAX LEVINE

From the Bacteriological Laboratory of the Engineering Experiment Station and the Iowa State College, Ames, Iowa

Within the past decade the indoor swimming pool has become an important adjunct to Y. M. C. A.'s, colleges, universities, city clubs, and diverse other organizations interested in the improvement of our physical welfare. In the larger cities there is considerable agitation for the installation of tanks in the public schools. In a hotel now under construction there is to be an 80-foot plunge bath for the use of guests.

The possibility of transmitting infectious diseases through pools is obvious. Manheimer[1] cites several striking instances of infections among bathers, and following the classification of Atkins, divides such infections under 3 heads: (1) intestinal, (2) eye and ear, (3) venereal. Respiratory disease might be added as a fourth. Lewis[2] remarks on the presence of grippe, colds, pneumonia, and sore throats among the frequenters of the pool at Northwestern University, and similar observations are recorded by Burrage[3] at Purdue, Whipple[4] at Brooklyn, Polytechnic, etc. During the two years' service of a tank at the Iowa State College, there has been no epidemic of any kind traceable to the pool, but there have been sporadic complaints of colds and sore throats. The danger of infection in pools has probably been over emphasized. Nevertheless, we should regard the swimming tank as a potential vehicle of infection and take the necessary measures to control its sanitary condition.

Since the beginning of this investigation articles have appeared by Manheimer,[1] and by Clark and Gage.[5] Their conclusions as to the efficacy of disinfection with hypochlorite are so at variance that the question of the proper control of pools is still an open one.

THE SWIMMING POOL OF THE IOWA STATE COLLEGE

The tank is located in a large well-ventilated and well-lighted room. The walls of the room are of white-enameled brick.

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[1] Jour. Infect. Dis., 1914, 15, p. 159.

[2] Eng. News, 1911, 65, p. 689.

[3] Ibid., 1910, 63, p. 740.

[4] Municipal Jour. and Engineer, 1911, 30, p. 577.

[5] Ann. Rep. Mass. State Bd. of Health, 1912, p. 347.

Construction.—The pool has a capacity of 90,000 gallons. It is 60 ft. by 30 ft., and the floor slopes so as to give 3 feet of water at the shallow end and from 7 to 8 feet at the deep end. The tank is of concrete with sides and bottom of white-enameled brick. Running around its top is a 6-inch gutter, or trough, which is connected directly with the sewer drains. This serves the triple purpose of an overflow gutter, an expectoration trough, and a handrail. The gutter is bounded by a ledge of white terra cotta about 1 ft. wide. Extending around, 4 inches below this ledge, is a 5-ft. concrete walkway so constructed as quickly to carry off all splash water, etc., into the sewer. Just off the walkway, on one side of the pool, are a shower room, a toilet, and a dressing room.

Operation and Supervision.—During school sessions, the pool is open from 4 to 6 p. m., and on 2 evenings a week. Occasionally it is used for class work between 10 a. m. and noon. By means of floor talks and printed notices posted in conspicuous places, the necessity and desirability of cleanliness are constantly brought to the attention of the bathers. Entrance to the pool is through the shower room, where an instructor is stationed to see that each person takes a proper shower with liberal use of soap. Even under these conditions of strict supervision it is doubtful whether an adequate bath is really taken by the majority of the bathers. The average attendance during Fall, Winter, and Spring is about 300 a week. During Summer about 500 people a week use the tank. Supervision is not so strict, since no medical examination is required of summer students and about half the frequenters are children under 14 years.

Water.—The water is obtained from 2 deep wells. It is of excellent quality bacterially, rarely having a count above 10 at body temperature, while tests for B. coli are uniformly negative in 100-c.c. samples. The mineral content, particularly iron, is extremely high. The iron is removed by mechanical filtration. Alum was employed at first, but discontinued. After filling the pool, the water is subjected to continuous filtration. The water is drawn through 2 pipes near the bottom at the deep end, pumped onto the filters, and returned to the pool through 2 pipes at the shallow end. About 50,000 gallons, or approximately one-half the capacity of the tank, are filtered daily. Occasionally fresh water is added to make up loss due to usage and leakage. The water is heated by steam forced in through 2 openings at the deep end of the pool, about 3 feet below the surface.

METHODS OF ANALYSIS

A review of the literature shows a lack of uniformity in methods of bacterial analysis of pools.

Ravenel[6] and Tully,[7] respectively, employed the count in gelatin at 20 C. and in litmus lactose agar at 37 C. For B. coli they used dextrose broth followed by confirmatory tests. Lewis[2] incubated for 72 hours at room temperature. Norton[8] plated on agar at 20 C. and on litmus lactose agar at 37 C. Manheimer[9] also plated on agar at room temperature, but employed plain agar at body temperature. He used the Jackson bile medium for B. coli. Another combination of media was gelatin at 20 C. and plain agar at 37 C., used by Thomas.[10] Clark and Gage[5] incubated litmus lactose agar and lactose bile at 40 C. for the body temperature count and for B. coli determinations, respectively.

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[6] Am. Phys. Edu. Rev., 1912, 17, p. 684.

[7] Am. Jour. Pub. Hyg., 1912, 2, p. 186.

[8] Am. Jour. Pub. Health, 1914, 4, p. 1016.

[9] Am. Phys. Edu. Rev., 1912, 17, p. 669.

[10] Jour. Ind. and Eng. Chem., 1915, 7, p. 496.

As a result of this lack of concordance in analytic methods, comparisons of the data from different pools are of little value. The necessity of some standard method of pool analysis is obvious.

In the study here reported, samples were collected once or twice a day for the first month and later at less frequent intervals. Unless otherwise noted, all samples were taken at the deep end, from 12 to 18 inches below the surface. Plates were poured within an hour after collection, and incubated at 37 C. for 24 hours. Both plain and litmus lactose agar (beef extract media) were employed. There were considerable and irregular variations between counts on plain agar and those on litmus lactose agar; finally, plain agar at 37 C. was adopted for the total count. Presumptive tests for B. coli were made by inoculating 1 c.c. into each of 5 Durham fermentation tubes containing lactose peptone bile. In some instances 10-c.c. and 0.1-c.c. samples were also tested for gas-formers.

EFFECT OF CONSTANT FILTRATION WITHOUT DISINFECTION

Distribution of Bacteria in Pool.—Samples taken from different parts of the tank showed some differences in bacterial content, but these variations were not of sufficient magnitude to be of any sanitary significance. The water from the filters is somewhat cooler and denser than that in the pool. A stratification might therefore result with a somewhat purer water at the bottom. While in use, the pool contents are reasonably well mixed, but during the long quiescent periods (20-22 hr.) depended upon for purification, stratification would tend to decrease the efficiency of the filtration process, for only the purer bottom strata would be passing through the filters.

Table 1 shows that some stratification does result. This could be avoided by changing the heating system in such way as to make the water entering the pool somewhat warmer than that already present in the tank.

TABLE 1

DISTRIBUTION OF BACTERIA NEAR THE SURFACE AND NEAR THE BOTTOM OF THE POOL AFTER CONTINUOUS FILTRATION FOR 6 DAYS, POOL NOT IN USE

Location	Bacteria per c.c.	
	1 ft. Below Surface	Bottom
Shallow end	1800	2300
Side	2500	1650
Deep end, middle	3200	1800
Deep end, corner	3400	1400
Average	2725	1780

Purification by Filtration.—Comparison of the bacterial content immediately after use with that from 18 to 20 hours later showed that the former was usually considerably higher. The reduction may be attributed to filtration, sedimentation, and possibly to the germicidal action of sunlight. During 20 weeks of operation with continuous filtration and no disinfection, the average bacterial purification was 60%. In a few instances, however, the count increased (see Table 3 and Chart 1). In consideration of the fact that only about half the water passes through the filters in 24 hours, the purification obtained (60%) would indicate that there was no multiplication of bacteria capable of developing on beef extract agar at 37 C.

Effect of Temperature on Bacterial Content.—There is some difference of opinion as to the proper temperature for plunges. From the point of view of the bacteriologist a pool is successfully operated if the bacterial count is low. This may be materially aided by a low temperature. The physical director, on the other hand, gages success by the attendance. This is favorably influenced by warmer temperatures. Of 5 physical directors in the Middle West, 1 reports for his pool a temperature of 70-72 F., another 76-83 F., and 3 maintain a temperature of 78 F. This is in marked contrast to the published reports of 7 pools in Massachusetts, Wisconsin, and Connecticut, in which the temperatures recommended are 70-72 F., except in one instance where 70-74 F. is prescribed.

At the Iowa State College the water is heated by forcing live steam into the tank. During the first few months it was extremely difficult to maintain a constant temperature. This variation, from below 70 F. to well above 80 F., afforded an opportunity to correlate temperature with bacterial content. Chart 1 shows a rather marked parallel between these two factors.

In Table 2 is indicated the effect of temperature as observed in a series of about 100 analyses. As practically all published reports recommended temperatures below 74 F. this temperature was selected for computing the table.

TABLE 2

RELATION BETWEEN THE TEMPERATURE AND THE BACTERIAL CONTENT OF A POOL

Bacteria per c.c. (Agar 37 C.)	Percentage of Samples		B. coli in 5 c.c.	Percentage of Samples	
	Below 74 F.	74 F. and Above		Below 74 F.	74 F. and Above
0-100	7.7	2.9			
101-500	38.5	7.4	Less than 1	42.9	21.2
501-1000	3.9	5.9	1	7.1	24.2
1001-5000	30.7	38.1	2	10.8	10.6
5001-10,000	3.8	22.2	3	21.5	12.2
10,001-50,000	7.7	20.6	4	3.5	10.6
Over 50.000	7.7	2.9	5 or more	14.2	21.2

Table 2 shows that B. coli was absent from 42.9% of the 5-c.c. samples when the temperature was below 74 F. as compared with 21.2% when the temperature was above 74 F. Of all samples taken when the temperature was below 74 F., 80.8% had bacterial counts below 5000, and 50% below 1000, while of samples taken with temperatures above 74 F., 54% contained less than 5000, and only 16.2% less than 1000 bacteria per c.c. We conclude from these results that, without the use of disinfectants, it becomes more difficult to maintain a swimming tank in good sanitary condition as the temperature rises above 74 F. To avoid chills the temperature of the room should be 4 or 5 degrees above that of the water in the pool.

In the lower part of Chart 1, the bacterial content of the pool before bathing is indicated by a continuous line; the content after bathing, by a broken line. In the upper part of the plot, the relative numbers of B. coli in 5-c.c. samples, before and after the tank was used, are shown by full and broken lines, respectively. On this plot are shown the analyses of all samples from October 27, when the tank was put into operation, to February 1, when it was emptied and cleaned.

Several facts are clearly demonstrated:

1. There is a marked fluctuation in the temperature, the total bacterial count, and the number of B. coli on different days. A rise in temperature is usually accompanied by an increase in bacteria.

2. From November to February there is a gradual, but fluctuating, decrease in the total number of bacteria, but the number of gas-formers increases. During the first 6 weeks B. coli was found only occasionally in 5 c.c. before use of the pool. After this period (with one exception) B. coli was constantly present in 5 c.c. It seems as if the organism had become adapted to its new environment.

3. On November 6 there was a marked drop in the number of bacteria, the count remaining low for about a week. During this period there was a considerable amount of sediment. This sediment became somewhat distributed throughout the tank during use, and in settling probably effected considerable purification by carrying down the bacteria mechanically. Manheimer noted that in a pool with a rather turbid water the bacterial content was relatively low.

4. The increase in B. coli after use of the pool is more striking than the relative increase in the total count.

EFFECT OF CONSTANT FILTRATION AND PERIODIC DISINFECTION WITH CALCIUM HYPOCHLORITE

Constant filtration alone, will at times keep the bacterial count low, but the preceding study indicates that this procedure cannot be relied on to maintain the pool in a sanitary condition. The danger of infec-

TABLE 3

BACTERIAL ANALYSES OF THE WATER IN THE SWIMMING POOL OF THE IOWA STATE COLLEGE, EMPLOYING CONTINUOUS FILTRATION WITH NO CHEMICAL DISINFECTION

Date	Time*	Bacteria per c.c. (Agar 37 C.)	B. coli in 5 c.c.	Temperature, F.	Remarks
1913					
10/27	B2	2,700	0	..	
28	A1	11,000	2	68	
29	B	73,000	1	76	Circulation of water begun
29	A	20,000	4	78	
30	B	64,000	3	72	Pump stopped at 12 m.; pump started at 6 p.m.
30	A	60,000	3	63	
31	B	17,000	0	62	Alum discontinued
11/ 1	A	18,000	0	68	
3	B	4,400	0	68	
4	B	10,000	0	72	
6	A	135	2	72	Pool turbid, with sediment on bottom
7	B	63	0	72	
7	A	269	3	68	
8	B	74	0	74	
10	B	18	0	..	
10	A	68	1	74	
11	B	110	1	74	
11	A	120	1	74	
14	A	330	2	74	Sediment removed
15	A	9,000	1	74	
17	B	6,500	1	76	
17	A	2,000	3	76	Pump and filtration stopped
18	A	2,600	4	78	
19	A	35,000	3	78	
20	A	16,000	1	74	
24	B	22,000	0	76	
24	A	19,000	4	76	
26	A	......	2	77	Pumps and filters started
29	A	16,000	1	78	
12/ 1	B	4,000	1	77	
2	B	2,300	0	75	
3	A	8,800	2	78	
3	B	18,500	1	78	
3	A	32,000	3	80	
4	A	16,000	2	86	
8	B	1,150	0	83	
9	B	2,200	0	78	
10	A	8,000	1	75	
11	A	5,500	1	76	
15	A	565	0	.	
16	B	......	0	..	
16	A	12,500	1	..	
17	B	......	0	..	
17	A	1,300	3	70	
18	B	......	1	..	
18	A	1,200	5†	..	
19	B	......	5†	..	
19	A	7,800	5†	77	
20	A	9,300	5†	74	Pool not in use Dec. 20 to Jan. 12
1914					
1/15	B	3,000	0	70	
15	A	1,600	2	73	8 inches of raw water added
16	B	625	4	68	

* A1 = sample taken during use or immediately after.
B2 = sample taken before pool was opened for the day.

† All five 1-c.c. samples tested were positive. There were therefore 5 or more gas-formers in 5 c.c.

TABLE 3—*Continued*

BACTERIAL ANALYSES OF THE WATER IN THE SWIMMING POOL OF THE IOWA STATE COLLEGE, EMPLOYING CONTINUOUS FILTRATION WITH NO CHEMICAL DISINFECTION

Date	Time*	Bacteria per c.c. (Agar 37 C.)	B. coli in 5 c.c.	Temperature, F.	Remarks
16	A	11,500	5†	73	
17	B	7,100	5†	78	
19	B	13,000	1	81	
20	A	475	5†	80	
21	B	2,500	4	78	
22	B	3,100	4	78	
22	A	2,000	4	77	
23	B	4,900	4	77	
23	A	4,300	5†	76	
24	B	950	4	76	
1914					
26	B	51	1	74	
26	A	120	5†	..	
27	B	185	3	72	
27	A	280	5†	72	
29	A	425	5†	72	
30	B	400	1	72	
30	A	450	5†	72	Pool emptied Feb. 5, sides washed, and pool refilled Feb. 9
2/11	B	450	0	56	
13	B	4,500	0	64	
16	B	32,000	0	76	
16	A	83,000	2	74	
17	A	27,500	5†	74	
18	B	7,500	5†	77	
18	A	21,100	5†	74	
19	B	8,000	5†	74	
19	A	4,000	5†	74	
20	B	1,400	5†	74	
23	B	4,600	5†	74	
25	B	1,000	3	78	
25	A	3,000	5†	77	
26	A	......	5†	76	
27	B	......	3	75	
3/ 2	B	5,400	2	73	
2	A	9,800	2	74	
3	A	35,000	1	76	Pool closed until 3/16. Filters continued in operation
16	B	900	0	74	
18	B	1,300	0	74	
18	A	2,400	2	73	
19	A	1,500	3	74	
20	A	1,700	0	74	
23	A	1,200	2	76	
31	B	2,500	1	76	Water low
4/ 3	B	1,200	0	76	Water low
3	A	8,000	0	76	Water low
4	B	700	0	74	Water low
6	B	1,250	0	72	Water low
7	A	440	0	72	18 inches of fresh water added
10	B	310	0	67	
10	A	1,850	0	70	
13	B	1,300	0	76	
13	A	1,800	1	77	
15	A	3,000	0	80	
16	A	8,400	1	78	
17	A	8,200	3	77	Pool emptied

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* A1 = sample taken during use or immediately after.
B2 = sample taken before pool was opened for the day.

† All five 1-c.c. samples tested were positive. There were therefore 5 or more gas-formers in 5 c.c.

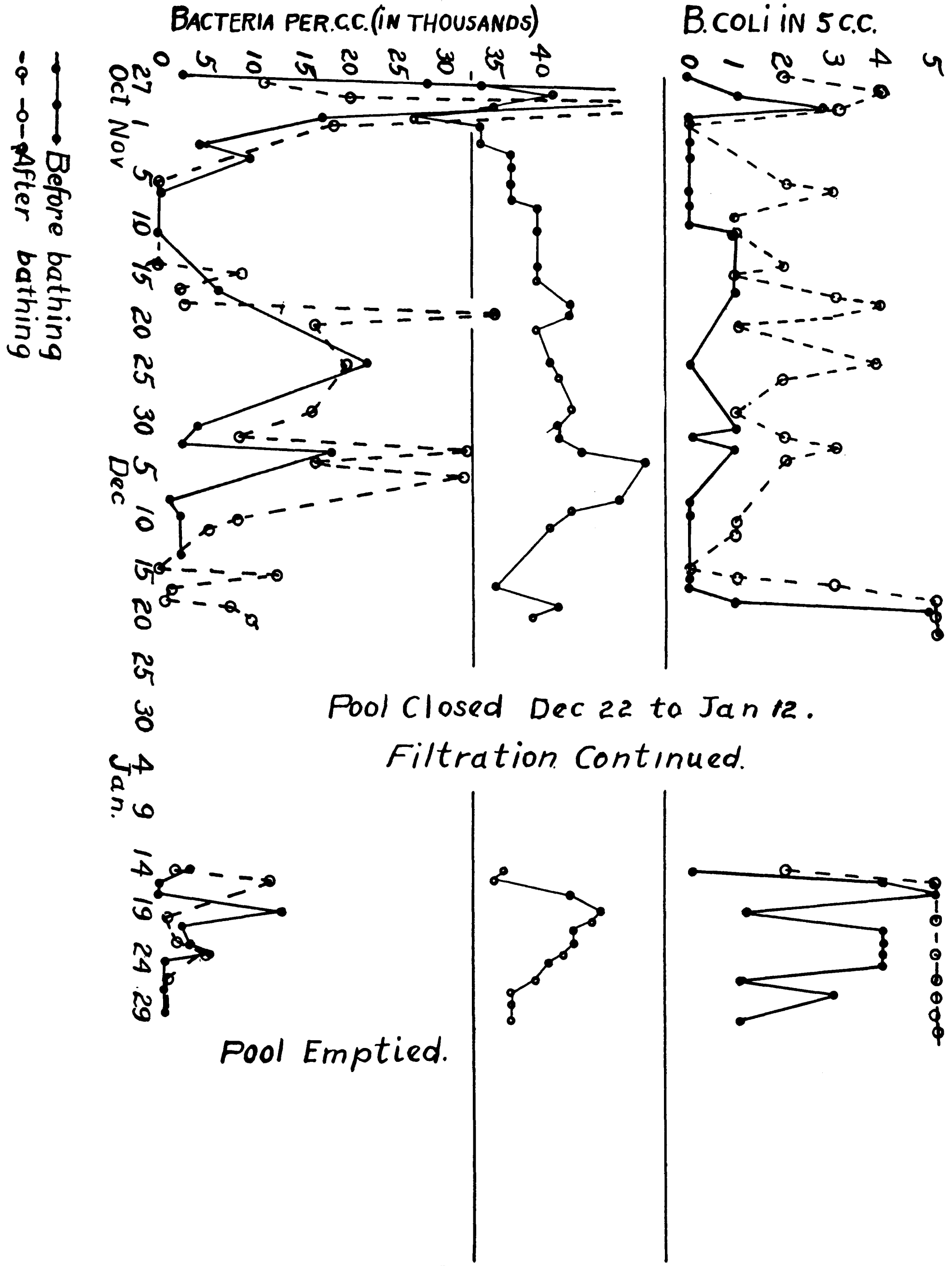

Chart 1. The results of the analyses of all samples from October 27, when the tank was put into operation, to February 1, when it was emptied and cleaned.

tion is that of direct contact with infectious material introduced by the bathers. Steps should be taken to make such material innocuous the moment it finds its way into the water. For this purpose, some disinfectant which is continuously acting and which is without effect on the bathers would be ideal. Copper sulfate, free chlorin, and bleach have been suggested. The last named, because of its success in water purification, has been highly recommended and most commonly employed. Tully,[7] Ravenel,[6] Lewis,[2] Manheimer,[1] Norton,[8] Rettger and Markley,[11] Bunker,[12] Burrage,[3] and others, have all recommended calcium hypochlorite and they suggest the addition of 0.5 to .1 part per million available chlorin 2 or 3 times a week.

TABLE 4

BACTERIAL ANALYSES OF THE WATER IN THE SWIMMING POOL WHEN CONTINUOUS FILTRATION WAS SUPPLEMENTED WITH PERIODIC DISINFECTION WITH CALCIUM HYPOCHLORITE

Date	Time	Bacteria per c.c. (Agar 37 C.)	B. coli in 5 c.c.	Remarks
1914				
4/27	5:30 p. m.	17,200	3	0.5 part per million available chlorin as hypochlorite* added at 5:45, being passed up and down in cheese cloth
27	7 p. m.	154	0	
28	5:30	4,700	3	
30	5:30	......	2	
5/ 1	5:30	42,500	1	
4	5:30	3,500	5	0.63 part per million available chlorin as hypochlorite added in suspension at 6 p. m.
4	7:00 p. m.	270	2	
6	5:30 p. m.	165,000	5	
7	5:30 p. m.	235,000	5	
8	10:15 a. m.	90,000	5	0.44 part per million available chlorin added as hypochlorite in suspension at 10:15. Pool very muddy
8	11:15 a. m.	27,000	2	
9	6:00 p. m.	9,600		
1915				
4/ 5	8 a. m.	700	0	
6	8 a. m.	4,000	0	0.75 part per million available chlorin as hypochlorite in suspension added at 6 p. m.
7	8 a. m.	28	0	
8	8 a. m.	12,000	0	
9	8 a. m.	52,000	0	
12	8 a. m.	34,300	0	
13	8 a. m.	7,600	0	0.75 part per million available chlorin as hypochlorite in suspension added at 6 p. m.
14	8 a. m.	81	0	
16	8 a. m.	9,100	2	
27	8 a. m.	2,500	0	0.75 part per million available chlorin as hypochlorite in suspension added at 6 p. m.
28	8 a. m.	17	0	
29	8 a. m.	1,400	0	

* Bleach contained 35.8% available chlorin (tested by J. S. Coye of the Engineering Experiment Station).

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[11] Eng. News, 1911, 66, p. 636.

[12] Am. Jour. Pub. Hyg., 1910, 6, p. 810.

Manheimer,[1] recognizing the desirability of continuous disinfection, advises the constant application of bleach in small quantities to the water as it passes into the filters. He states that this gradual addition is preferable to periodic applications of larger quantities to the tank proper. Clark and Gage[5] in a test of the swimming pool at Andover, Mass., found that the continuous addition of 0.3 part per million available chlorin to the water passing through the filters resulted in a purification of only 68%. They obtained more satisfactory results by the periodic application of bleach directly to the tank.

Results obtained with hypochlorite at Ames.—In the first of the experiments to be described, the disinfectant was placed in a bag and drawn across the surface. In all other tests the bleaching powder was suspended in water and sprinkled over the surface.

Table 4 shows that the application of from 0.5 to 0.75 part per million available chlorin generally brings about a reduction of over 98% in a few hours; but that the germicidal action is quickly lost, is indicated by the rapidly rising counts 24 to 48 hours after the introduction of hypochlorite. Available chlorin, 0.75 part per million, was much more efficient towards reducing the count of B. coli than towards reducing the total count.

Thomas,[10] in a study at Lehigh University, using 0.83 part per million available chlorin obtained similar results, from which he concludes: "To add 2.5 parts per million of the hypochlorite every day would probably solve the problem from a bacteriological standpoint, but the odor would be too offensive for this form of treatment to be considered."

Norton,[8] in a recent study of the Y. M. C. A. pool at Cambridge, Mass., employed 0.75 part per million available chlorin, or 1 pound hypochlorite in 55,000 gallons of water per day. The chemical was added every night after the bathers left. He concludes: "Addition of hypochlorite causes an immediate reduction in the number of bacteria, and this number is kept down by this and the rest of the purifying system to a reasonable limit for about four weeks. The same is true of the gas-forming elements. In the opinion of the author [Norton] the two main factors in keeping the bacterial count low are the addition of hypochlorite and the sedimentation . . ." The data he presents show that 75% of the samples had a bacterial content of from 18,000 to 300,000 on litmus lactose agar and that B. coli was present in numbers of from 1 to 10 in 50% of 5-c.c. samples. Unless we accept counts of from 18,000 to 300,000 as low for swimming pools, his conclusions as to the efficacy of hypochlorite are not warranted by the published data.

The work of Clark and Gage[5] on the value of hypochlorite in swimming pools is probably the most extensive yet reported. They found that daily application kept the count reasonably low for the first few weeks, but that soon the total and B. coli counts began to rise rapidly, necessitating an increase in the amount of disinfectant. Their experience with the periodic use of bleach was similar. The count was low only when free chlorin was present in the water. Even with such enormous quantities as 3.7 parts per million available chlorin the count was kept down only for a day or two, and on days when an excess of hypochlorite was used, the number of bacteria exceeded 10,000 per cubic centimeter more than one-third of the time.

They draw the following conclusion: "The results . . . show quite clearly that occasional disinfection or regular disinfection [with hypochlorite] at intervals of several days cannot be relied upon to maintain a water of low bacterial content . . ." They also note that there were many complaints of burning and smarting eyes.

Enough has probably been said to point out that the use of bleaching powder has not solved the question of the sanitary control of swimming pools. The advocates of hypochlorite base their opinions largely on a priori reasoning from its success in water-purification. A swimming pool is not a water supply, except in the sense that the novice will use it as such. A water supply after treatment is protected against repollution. A swimming pool is constantly receiving pollution and should therefore be constantly disinfected. Roberts[13] points out that disinfection should be continuous, but that an occasional complete sterilization would be advantageous. Hypochlorite may be employed for an occasional sterilization, but its rapid decomposition, its irritating effect on the eyes, and possibly harmful influence on the teeth, eliminate bleach for use in continuous disinfection of swimming pools.

EFFECT OF CONTINUOUS FILTRATION AND DISINFECTION WITH COPPER SULFATE

That copper sulfate under proper conditions is an efficient germicide is well known, but its value as a swimming-tank disinfectant has not been adequately tested. Stokes[14] used $CuSO_4$ in 1 : 100,000 dilution and found that algae and bacteria were destroyed. Manheimer[1] found that of 6 pools practicing disinfection, 3 used $CuSO_4$. Rettger[11] had to abandon $CuSO_4$ on account of the hardness of the water, while Thomas[10] points out that with a hard water softened by treatment with alum and mechanical filtration, 0.4 part per million $CuSO_4$ was more efficient than 0.83 part per million hypochlorite.

During the summer of 1915, $CuSO_4$ was substituted for bleach at the Iowa State College and the results observed for 3 weeks. The bacteriologic analyses are given in Table 5. During the observation period 4 pounds of the chemical were added. The disinfectant was

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[13] Eng. News, 1912, 67, p. 73.

[14] Am. Med., 1905, 10, p. 1075.

TABLE 5

BACTERIAL ANALYSIS OF WATER IN THE POOL AT IOWA STATE COLLEGE WITH $CuSo_4$ DISINFECTION AND CONTINUOUS FILTRATION

Date	Time*	Bacteria per c.c. † (Agar 37 C.)	B. coli in 5 c.c.	Remarks
1915				
7/ 5	B	80	5	Before addition of $CuSo_4$
5	A	9	0	1½ hr. after adding 1.5 part per million of $CuSo_4$. Pool used by 70 boys. Water in pool muddy
6	B	36	0	
7	B	19,300	0	
8	B	1,870	0	Pool cleaned. 1.5 parts per million $CuSO_4$ added after taking sample
8	A	178	0	3 hr. after addition of $CuSo_4$. Pool used by 80 boys
9	B	155	0	
10	B	142	0	
13	B	57	0	3 parts per million $CuSo_4$ added after taking sample
13	A	4	0	3 hr. after adding $CuSo_4$. Pool used by 70 boys
14	B	11	0	
15	B	12	0	
16	B	50	0	
19	B	120	0	18 inches of fresh water added
20	B	535	0	
21	B	2,520	0	
22	B	1,900	0‡	

* B = before pool was opened for use.
A = after pool was used, usually 2 hours.

† These counts were made on agar in which the peptone of the Digestive Ferments Co. was used, while previous counts were made with Witte's peptone. The bile for the presumptive tests for B. coli was made with Witte's peptone in all cases.

‡ B. coli present in 10 c.c.

TABLE 6

BACTERIAL CONTENT OF THE IOWA STATE COLLEGE SWIMMING TANK WITH DIFFERENT METHODS OF TREATMENT

Bacteria per c.c. (Agar 37 C.)	Percentage of Samples		
	Continuous Filtration	Filtration and Disinfection with Calcium Hypochlorite	Filtration and Disinfection with Copper Sulfate
0-100	5	15	47.
101-500	15	10	23.5
501-1000	7	0	5.9
1001-5000	34	25	17.7
5001-10,000	14	15	5.9
10,001-50,000	21	15	0
50,001-100,000	4	10	0
Over 100,000	0	10	0
B. coli in 5 c.c.			
Less than 1	29.5	52.5	94.1
1	19.0	9.5	0
2	11.5	19.0	0
3	11.4	0	0
4	8.6	0	0
5 or more	20.0	19.0	5.9

introduced just before the pool was opened. A bag containing the $CuSO_4$ was drawn along the surface of the water until all was dissolved. This procedure usually took about 15 minutes.

From Table 5 it is apparent that, under the conditions present in this pool, $CuSO_4$ is very efficient in keeping down the total bacterial count, and also the count of B. coli.

A comparison of the results obtained with filtration alone, with filtration supplemented by disinfection with hypochlorite, and with filtration supplemented by copper sulfate, leads to the conclusion that the latter method is the most efficient. This is shown in Table 6.

B. coli was absent from 29.5% of 5-c.c. samples before disinfectants were employed; from 52.5% of samples after hypochlorite was used; and from 94% after copper sulfate. The total bacterial counts particularly, indicate that copper sulfate is superior to bleach as a disinfectant for swimming pools. If we compare copper sulfate and bleach when the latter was employed in quantities of 0.75 part per million, or more, available chlorin, we shall find that they had about the same effect on B. coli—94% of 5-c.c. samples were negative with the copper sulfate and 91% with bleach; but the total bacterial content was considerably lower with copper sulfate (see Tables 4 and 5).

SUMMARY AND CONCLUSIONS

Swimming pools are being rapidly adopted throughout the country. Unless they are adequately protected against infectious matter and their sanitary conditions controlled, they may serve as a vehicle for the transmission of disease.

A sanitary standard for plunges would be desirable, but it is necessary first to standardize the methods of analysis in order to obtain comparable data on which to base such a standard.

At the pool of the Iowa State College continuous filtration effected a reduction of 60% in the bacterial count. For 6 weeks presumptive tests for B. coli in 5 c.c. before use of the pool, were usually negative. After that time positive tests became more frequent until gas-formers were constantly present in 1 c.c. and occasionally in 0.1 c.c. During this period the total count on agar at 37 C. decreased irregularly.

With continuous filtration and without disinfection the sanitary condition of the pool, as indicated by the total and the B. coli counts, was better when the temperature of the water was below 74 F. than it was when above. The temperature of the room should be higher than that of the water.

Continuous filtration alone is insufficient to maintain a tank in a sanitary condition. Filtration should be supplemented with disinfection.

The bathers are constantly introducing pollution and possibly infectious matter. To off-set this continuous pollution disinfection must also be continuous and the disinfectant should be most effective at the time when the pool is in use. It is in these respects that the periodic application of such substances as calcium hypochlorite, after the tank is vacated, falls down. Bleach is excellent for an occasional or terminal sterilization, but on account of its irritating effect on the eyes and possibly harmful influence on the teeth, it cannot be employed efficiently for continuous disinfection.

Copper sulfate is very efficient for swimming-pool disinfection. It is cheaper, has no irritating effect, its disinfecting action is slower, and consequently more applicable to continuous disinfection, than that of hypochlorite. The copper sulfate could be added just before the pool is opened and thus its maximal efficiency would be exerted during the period of maximal pollution. Filtration supplemented by disinfection with 1 part per million $CuSO_4$ 3 times a week and, if desired, an occasional sterilization with calcium hypochlorite will keep a swimming tank in good sanitary condition for several months.